

RESEARCH DEPARTMENT

COLOUR FILM AND COLOUR TELEVISION

Technological Report No. T-169

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SUMMARY

This report discusses the use of colour film for colour television, with particular reference to the choice of film stocks.

1. INTRODUCTION

Colour films which are acceptable for optical projection may not prove satisfactory when scanned in a colour telecine. Colour television presentation requires a film of lower overall contrast with a different characteristic relating the light-transmission of the film to the brightness of each part of the original scene. Attempts have been made by the Film Department and the Research Department of the BBC to find colour photographic processes which will produce prints better suited to colour television but the requirements are sufficiently different from those of optical projection to create considerable difficulty.

2. DIFFERENCES BETWEEN TELEVISION DISPLAY AND OPTICAL PROJECTION

The contrast-handling ability of a colour television system is limited primarily by the display tube. When viewing in complete darkness, flare in the tube faceplate may raise the brightness of scene blacks to about 1/30th highlight brightness and when typical ambient lighting is used* the contrast falls to about 20 : 1. These figures relate to the latest shadow-mask tube with bonded neutral faceplate when used to display fairly small areas of brightness surrounded by a field composed of medium-fine picture detail, not including a large expanse of sky.

Viewing conditions in the cinema are, of course, carefully controlled and hardly any ambient light is allowed to fall on the screen. Even in the presence of flare due to the optical system of the projector the contrast displayed is typically above 100 : 1. Any curtailment of this contrast by the addition of a constant due to ambient light would produce a

compression of the brightness scale in the shadows of the picture displayed. As a problem in television engineering this would be regarded as requiring "black stretch" to compensate the crushing of shadow detail. Black-and-white films intended for the higher contrasts of optical projection may be given an overall contrast-law which reduces the slope in the highlights and lighter greys by working around the toe of the characteristic of the print film; the darker parts of the picture are then of higher relative contrast, thus producing black stretch.

In colour television, where the contrast of the display is so much reduced by the relatively severe flare and unfavourable viewing conditions the "flattening" of the display brightness characteristic is, of course, very pronounced and, for good subjective presentation of the picture information, considerable black stretch is required. In selecting films for colour television, this is often referred to loosely as the requirement for a "low-gamma print" although it does not accurately state the case. It is unfortunate and rather misleading that television engineering oversimplifies the contrast law characteristic problem by attaching a value of gamma even though the characteristics do not very closely resemble a pure power law. In photographic practice the term "gamma" is taken to mean the slope of a short central part of the curve obtained by plotting density against the logarithm of the exposure, and it does not describe departures from a straight line in the toe or shoulder of the curve. The absolute value of gamma thus defined is of less interest in films for television presentation than is the shape of the characteristic relating film transmission with scene brightness.

In making photographic prints on paper where the contrast is very restricted, the normal photographic technique is to use an emulsion which has a long, rounded toe in its Density/Log. Exposure curve and, in a manner similar to operating an

* About 42 lux (4 ft-Candles) falling on the face of the tube.

image orthicon camera tube around the knee, to arrange the exposure so that the mid-greys and lighter greys fall on the lower-slope portion of the characteristic leaving shadow detail in the picture to be thus relatively stretched. The stated photographic gamma of the process now relates to the slope in the shadows.

It would seem that a similar technique is desirable for films intended for television since both television displays and reflexion prints require the principle of black stretch operating at much lower contrast than that required for film projection.

A further point of importance is that normal practice in making colour films for the cinema raises the gamma (in the strict photographic sense) of the process to 1.6 or even 2.0 at high densities in order to accentuate differences between the amounts of the three dyes and so increase saturation. This procedure tends to counteract the inevitable loss of saturation at the higher luminance levels caused, for instance, by overlap of the spectral absorption bands of the dyes in the colour film.

The poor contrast-handling ability of the television display therefore renders it unsuited to good reproduction of films designed for presentation in the cinema theatre and television is faced with the necessity for adopting one of the following special measures:

- (1) To make special colour films for television presentation in which the saturation of the colours is high yet the light-transmission/scene-brightness characteristic is so shaped that shadow detail, in particular, shall not be lost by being unduly compressed in contrast.
- (2) To develop means whereby existing high-contrast, high-gamma films can be scanned in a colour telecine and the signals thereafter modified by matrixing and gamma-correction in such a manner that the information on the film will be displayed acceptably upon a typical receiver, notwithstanding its limitations.

Two further specialized television applications for colour film should be mentioned. Film inserts for studio productions will undoubtedly be required in colour, and it will be of great importance to match the high saturations combined with high luminance achieved in the output of a colour television camera. No process of colour photography can, on its own, approach this performance but with the aid of electronic masking techniques in the film scanner (see Section 5) a satisfactory result will probably be obtained.

Secondly, there will be a requirement for colour telerecording on film mainly for distribution overseas. It seems certain that the results will be inferior to video tape recording and hence the domestic use may be small.

3. MAKING FILMS SPECIALLY FOR COLOUR TELEVISION

It is not possible to vary the gamma of a colour photographic process and variations in development procedure which are quite acceptable with black-and-white film may result in gross colour distortion. In making films specially suited to the contrast law of colour television displays, it is therefore necessary to use a film stock specially designed to have the requisite scene-brightness/light-transmission characteristic.

The most widely-used colour film for professional purposes is Eastman Negative Type 5251 printed on to Eastman Colour Print film Type 5385 but this process was developed for the cinema industry and produces the conventional high-gamma, high-contrast result undesirable for television. The requirement to produce more than one copy of every film exists in television no less than in the cinema industry but this does not necessarily restrict the choice of film stock to the negative-positive process. Many colour films, particularly those intended for amateur use, employ a reversal process so that the film projected is that which passed through the camera but some can be duplicated upon other reversal stocks.

At the present time only one colour film appears to have a scene-brightness/film transmission characteristic which successfully offsets the "flattening" of shadow detail by the shadow mask display. This is Ektachrome Commercial film, generally known as E.C.O., which combines a suitable light-transfer characteristic with good saturation of the reproduced colours. Although a reversal stock, this film is not intended to be projected, and the usual way of using it is to print it upon a special Kodachrome reversal print stock (not to be confused with the popular Kodachrome II) with a high gamma. The entire process (a "reversal-reversal" process) gives a contrast law suitable for optical projection. It is found, however, that if E.C.O. is used to make the print, as well as being used in the camera, a low-gamma, high-saturation print can be obtained and under experimental conditions this gives the best results so far examined. It seems that the scene-brightness/film-transmission characteristic of this rather unusual film, intended only as a camera stock, is well suited to television. The difficulty is that the process appears to require

abnormally close control to give consistent results, and these might not be obtained in ordinary operational practice. At the moment, this film is normally available only in 16 mm gauge although a quantity of specially-produced 35 mm film has been provided for our experiments.

Other reversal films, for example, Kodachrome II, Ektachrome-X, etc., are primarily intended for amateur use and at present cannot be duplicated satisfactorily since their characteristics have not been selected with this purpose in view.

Approaches to manufacturers have promoted thoughts of new colour films specially designed to facilitate the required end-product. A low-gamma, low-contrast, high-resolution reversal Ektachrome duplicating film is being developed by Kodak and sample quantities of this film are expected to be available in the summer of 1966. This film would probably be well suited to making copies from E.C.O. originals but may also have an application in conjunction with Ektachrome-X which is higher in gamma than E.C.O. but is more sensitive and could prove to be a very suitable stock for colour telerecording if it can be duplicated. In long lengths for professional use Ektachrome-X is sold as Ektachrome-MS. The precise title of the proposed Ektachrome duplicating film is not yet known.

There is reason to believe that an alternative and very attractive approach is under development by the French Kodak Company; this is a low-gamma version of Eastman positive colour print film. If it could be given a suitable degree of "black stretch" as in the case of E.C.O., it would permit suitable copies to be made from existing colour negatives as well as providing a means of printing new films. Other advantages would include simpler processing since there are obviously less steps in a negative-positive process than in a reversal-reversal process.

Yet another approach is being adopted in America and is advocated by the commercial interests of the Kodak organisation. This is to use the existing Eastman Colour Types 5251 and 5385 in a negative-positive process but to modify the lighting of the scene so that it has a very low-contrast, low-gamma appearance which to some extent offsets the high-gamma photographic process upon which it is recorded. This approach, however, appears to confuse a simple restriction of the contrast with the real need to compensate for the effects of crushing shadow-detail in the display tube. Examples of this technique admittedly have a reduced contrast but the reproduction nevertheless appears to be unsatisfactory, because the relationships between individual luminance levels in the scene have become disturbed both by flare in the

display tube and by the high gamma which still remains in the photographic process. The two distortions are not complementary. This expedient is being used in America because of the absence of a satisfactory conventional photographic process but, of course, it can in any event only be applied under carefully-controlled and lavishly-lit studio conditions which are not often available for the BBC's filming programmes.

4. REPRODUCING EXISTING COLOUR FILMS

Even if a satisfactory method of producing suitable colour films were immediately available, there is still a very large number of existing feature films to be reproduced and there will no doubt always be a proportion of films primarily intended for cinema presentation. It is possible to reduce the contrast of these films by reduction of the gamma of the signals after scanning. This facility is included in experimental electronic masking units being developed by Research Department and it is found in practice that the gamma of the signals can be reduced to the extent that a satisfactory presentation of films intended for cinema use can usually be made. It must, however, be pointed out that high contrasts in the film must entail greater densities than the flying-spot scanner can handle with good signal-to-noise ratio and noise in the blacks will be further exaggerated by the increased amplification of the additional gamma reduction. Any residual colour errors in the darker tones of film will also be exaggerated so that this is a less desirable approach than having a special print for television transmission. It must also be borne in mind that overseas users of films made by the conventional process may not have the masking and gamma-correction facilities required.

5. MATCHING COLOUR FILM TO TELEVISION CAMERAS

In a complete programme taken from film there will be no absolute reference to the saturation of any particular colour except where the viewer has an accurate memory of what a colour should look like, as in the case of a post box or omnibus. Where, however, it is required to cut between film and live television cameras, an accurate match for colour and luminance is essential. The nature of the dyes used in colour film make it impossible for the film to reproduce some saturated colours with high luminance and the results will generally be inferior to those of the colour television camera. When a colour film is scanned in a television system the information is subjected in turn to the effects of colour photography and colour television

and the distortions of these two processes are multiplied together; the reproduction is therefore usually worse than that obtained by optical projection.

A knowledge of the inevitable distortions due to the dyes in the photographic process permits correction to be applied to the electrical signals after the film has been scanned. With this technique, known as electronic masking, we no longer set out to reproduce the image on the film but now attempt to obtain a good reproduction of the original scene. This procedure can be made to give a more accurate reproduction than the film is capable of alone, since saturation and luminance accuracy can be restored. It is believed that with the aid of these techniques satisfactory intercutting of film and colour television will prove possible.

6. TELERECORDING

In telerecording on colour film great care must be taken to minimise the further loss of saturation, with other distortions, which may arise because the information will now have been subjected to the colour television process twice, as well as to colour photography.

Selection of cathode-ray tubes to give maximum energy at wavelengths suited to the sensitivities of the colour film stock and an elaborate process of colour filtration by means of dichroic mirrors, interference filters and organic filters is necessary to separate as far as possible the three colour components of the recording. The object must be to ensure that the red signal fed into the colour telerecorder shall stimulate only the red-sensitive layer of the film, and similarly for the green and blue components. The shadow-mask tube is considered unsuitable for telerecording from many points of view and therefore the experimental telerecording display nearing completion contains three separate cathode-ray tubes, their images being combined in register by the dichroic mirrors already mentioned.

Preliminary tests indicate that Ektachrome-X (or Ektachrome-MS) film will be most suited for the original telerecording and it is therefore to be hoped that the low-contrast duplicating stock mentioned in Section 3 will prove to be successful.

It will probably be desirable to introduce some correction of the contrast law in the signals fed to the colour telerecording display, and possibly some pre-correction for unwanted absorptions by the dyes of the film to be used. It is intended to investigate also the properties of electronic flare correction and vertical aperture correction.

Colour film telerecording experiments in

Research Department are at present confined to obtaining accurate colorimetry in a still frame, although a display suitable for film telerecording is under development in the BBC Designs Department. The choice of film transport mechanism is dependent upon the gauge of the film to be adopted.

7. FILM GAUGE

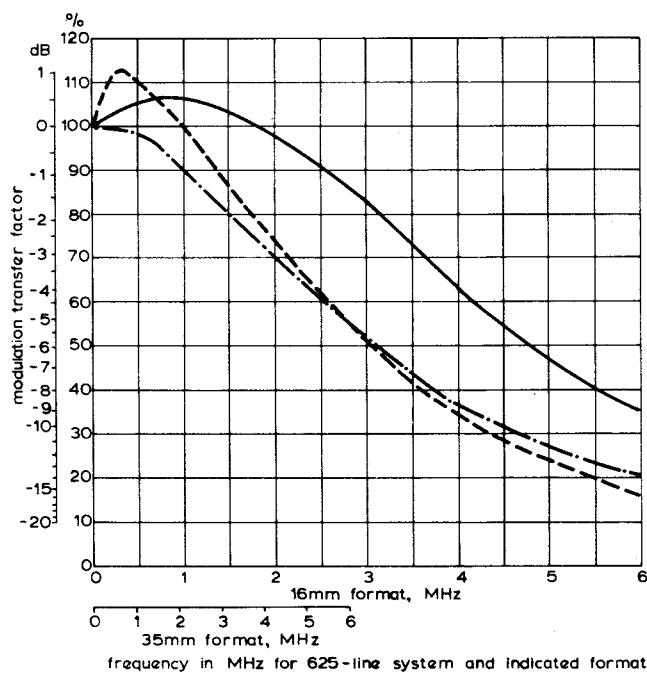
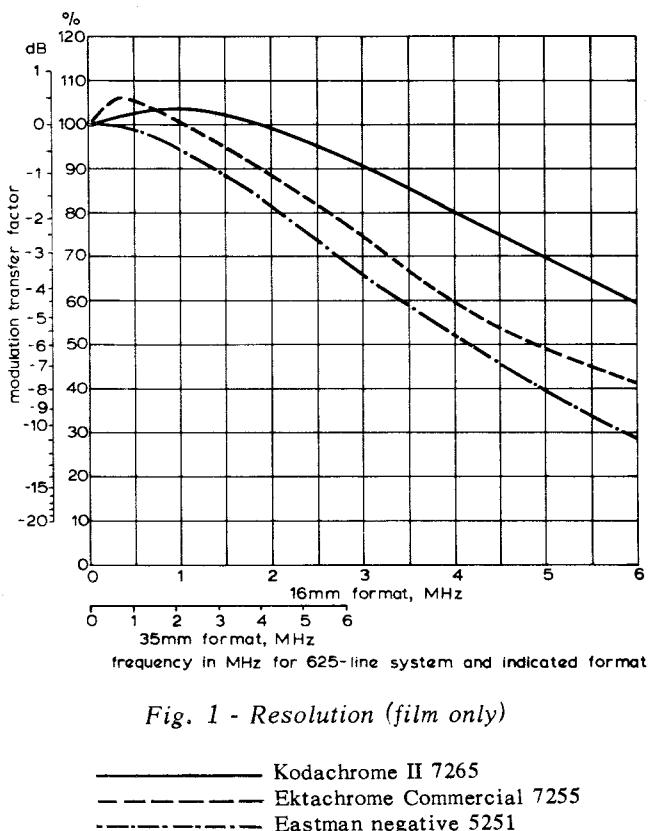
Equivalent colour film processes can usually be made available in both 16 mm and 35 mm gauges so considerations of colorimetry and sensitivity are common to both. (It is assumed that 35 mm E.C.O. film would become available if a regular requirement arose.)

Kodak Research Department, Harrow, have measured the resolution of the latest versions of the principal film stocks under investigation; these results must be regarded as confidential. Fig. 1 shows the resolutions of Eastman Negative Type 5251 and E.C.O. compared with Kodachrome II. The latter film is included in the results because it has the highest resolution of any colour film in regular supply but unfortunately it is not suitable for our use because it cannot be duplicated successfully. It will be seen that the two films capable of use in television are both more than 7 dB down at 5.5 MHz (Mc/s) when used as 16 mm even though we have so far neglected the essential process of making a print.

Fig. 2 shows the effect of multiplying together the resolution of a camera film of the type stated and printing it in an hypothetical, lossless printer on the print stock shown. From this it will be seen that either of the usable processes are more than 13 dB down at the cut-off of the 625-line system when used in the 16 mm format. It must, however, be remembered that we have yet to find a 16 mm printer which introduces less than 3 dB resolution loss at the equivalent of 5.5 MHz and it would certainly not be unreasonable to include 2.0 dB loss at this frequency for the camera lens. It therefore follows that we cannot expect 16 mm film to be better than 18 dB down at 5.5 MHz under the best operational conditions and this result corresponds remarkably well with the previous experiments carried out by Television Operations and Maintenance Department and in Research Department.

If the same film stocks are considered in 35 mm gauge, it would seem that an overall figure for the resolution at 5.5 MHz would be about 6 dB down, including the effect of lens and printer.

The severe loss of resolution due to the use of 16 mm film might render this gauge unusable for many applications of colour television, so another



approach might be to use 35 mm camera stock and make reduction prints on 16 mm film. Fig. 3 shows the effect of doing this and it will be seen that the loss of resolution at 5.5 MHz is reduced to about 6.5 dB, not allowing for losses in the original lens or the reduction process. Unfortunately, experience to date has been that losses in the reduction printer generally offset any advantage that might be gained from the use of a 35 mm original, but there is no very sound technical reason why this should be so. If the losses in the reduction printer could be reduced to about 3 dB and allowing 1.5 dB for the original (35 mm) lens, a 16 mm reduction print from a 35 mm original would be about 11 dB down at 5.5 MHz. The improvement over an all-16 mm process would be about 7 dB, so where it is essential to provide a 16 mm print this method might well be worth investigation.

The impression gained from a study of these minimum losses of resolution is that 16 mm film for colour television is unlikely to be desirable except in those applications where portability of the camera equipment and the undoubtedly ease of handling 16 mm film outweighs the need for picture quality.

Many of the considerations in choice of film gauge apply equally to colour film or black-and-white; the latter is dealt with exhaustively in Television Operations and Maintenance Department Report "Extension of 16 mm Working".

Film grain and telecine noise will, however, assume more importance in colour television since colour signal transmission systems are particularly susceptible to noise components in the region of the colour subcarrier frequency. This noise appears in the decoded picture as low-frequency "cross-colour" noise of high visibility.

For a given sensitivity, colour film has substantially more grain than that of a black-and-white process, and the poor resolution, already discussed, means that more aperture correction will be necessary in the film scanning process. Even if colour film had the same resolution and grain as black-and-white film, the effect of coding and decoding the colour signals would accentuate the difference in noise performance between 35 mm and 16 mm gauges.

8. COLOUR FILM PROCESSING

No very detailed investigation has yet been carried out into the precision with which commercial processing of colour film can be obtained but the indications are that the general standards of commercially-available processing service will be

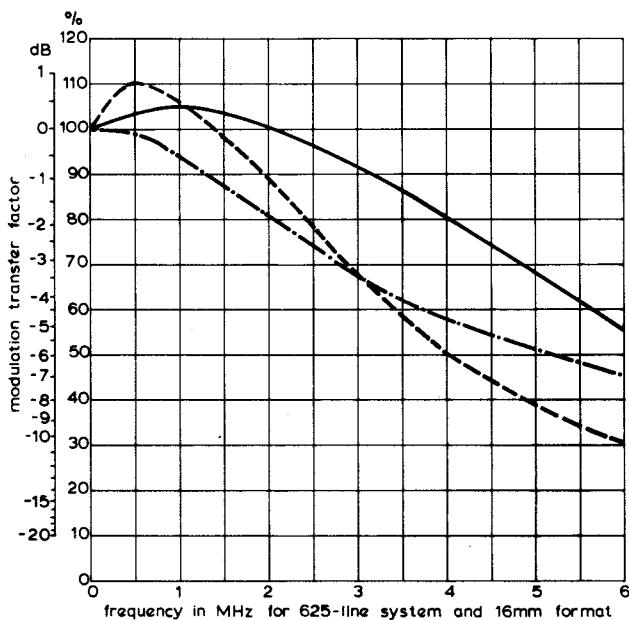


Fig. 3 - Resolution ("perfect" 16 mm reduction print from 35 mm original)

printed on:-
 16 mm Kodachrome II
 16 mm Ektachrome Commercial
 16 mm Eastman positive
 printed from:-
 35 mm Kodachrome II
 35 mm Ektachrome Commercial
 35 mm Eastman negative

inadequate for good-quality colour television presentation. With the present techniques, it is sometimes necessary to make several attempts at correct balance before carrying out a fairly large run of duplicates for general release. The television requirement is likely to be between, say, two and six copies so that if several attempts were necessary before satisfactory prints were obtained, the cost would become prohibitive. A new approach to colour film processing may be necessary before television finds a satisfactory and economical means of working to close tolerances. A solution to the problem may be in direct application of viscous developing agents to the film; after the appropriate time, these are washed away and thus used only once. Processing machines employing this principle may offer much greater consistency than the very large recirculating baths used in processing laboratories for high-speed processing of large quantities of film, and could, if necessary, be operated within the BBC since the chemicals are pre-packaged and the machine can be operated satisfactorily on an intermittent basis.

Similarly, it might well be advantageous for the BBC to carry out its own printing using step printers of high quality, because the high printing speeds required by commercial processing labora-

tories and the use of continuous roll printers cannot produce the best possible result. The additive exposure principle, in which the light source consists of three separate narrow-band excitations for the three sensitive layers in the print stock could be used in order to improve colour saturation in the print. To give the quality of resolution and steadiness which we require, the printer would necessarily operate at a very low speed which would be uneconomic in commercial practice.

9. CONCLUSIONS

It is difficult to draw firm conclusions in the present lack of practical experience, but the following points emerge:

- (1) There is an important requirement for a new colour film stock designed to suit the particular needs of colour television.
- (2) Electronic masking and other correction techniques will be invaluable in improving the colour quality obtained from scanning film. There is a good chance of acceptably matching the performance of a live colour television camera.
- (3) The practicability of obtaining colour tele-recordings of adequate quality has not yet been established. There is a reasonable expectation of acceptable colorimetry, but resolution, registration, flare, film transport, gauge of film, monitoring and many other aspects still remain to be investigated.
- (4) There is little hope of 16 mm film providing good-quality colour television. The resolutions of the basic film stocks, neglecting lenses, printers and the telecine losses are alone sufficient to cast doubt on the usefulness of this gauge except in cases where the use of 35 mm is precluded by some insurmountable difficulty such as size and weight of apparatus.
- (5) Commercial processing appears unable to work to the tolerances we need without a succession of approximations which would be prohibitively expensive. The BBC should investigate the new viscous methods of processing, but would need to devise special methods of control, as was done for black-and-white telerecording.
- (6) Commercial printing, particularly reduction printing, leaves much to be desired and it might be found desirable for the BBC to carry out printing and processing with its own staff, on machines modified to its special requirements.